Recommendations from the Mate Choice Subgroup
of the Island Fox Conservation Working Group

Summary: On March 30, 2004 a teleconference orchestrated by Mr. Keith Rutz (Channel Islands National Park) was held to discuss options for increasing productivity and decreasing aggression in the Island fox Captive Breeding facilities. In addition to Mr. Rutz, Dr. Cheri Asa (St. Louis Zoo), Dr. Devra Kleiman (Smithsonian Institution), Dr. Kathy Ralls (Smithsonian Institution), and Dr. Gary Roemer (New Mexico State University) were in attendance. Dr. Roemer orchestrated a second conference call on May 4, 2004.

Recommendations: The following recommendations are categorized into two separate but equally important foci: (I) Pen Design and Mate Choice Experiments, and (II) Risk Assessment, PVA, and the Development of a Mainland Research and Breeding Facility. Within each category, recommendations are prioritized by number and include the application of various approaches/policies and the establishment of research facilities to enhance propagation and reduce aggression within the captive facilities. These recommendations should be considered urgent with implementation beginning sometime this year.

I. Pen Design and Mate Choice

1. Alterations to Current Pen Designs – The current pens housing captive foxes are either L- or U-shaped and have proven adequate in many cases to allow successful breeding especially on Santa Rosa Island. Nevertheless, overt male aggression toward females recently occurred in six new pairs formed at the existing Island fox Captive Breeding Facilities (San Miguel, n = 2; Santa Rosa, n = 3; and Santa Cruz, n = 1). On San Miguel Island, a female died of the injuries sustained. This female was the last wild fox captured on San Miguel and thus, an important potential founder. The recent injuries and resulting mortalities of females suggest that modifying pens to increase "escape habitat" might lessen the potential for aggressive interactions. First, creating complete visual barriers between cages may be essential because aggression exhibited within a pair bond may happen because of cross-cage inter-male aggression. Thus, if males (and females) are interacting aggressively with foxes in neighboring cages, they may displace that pent-up aggression on their respective mate. One way to potentially reduce intra-pair aggression is to reduce contact across cages as much as possible.

Second, additional visual barriers and nesting sites within cages may provide for more "escape habitat." It has been noted that males and females in the same cage frequently rest together regardless of their breeding success (K. Rutz, pers. obs.). This lack of difference in resting behavior may simply be a consequence of limited resting sites. If given the opportunity, members of unsuccessful pairs may opt to rest apart, this could reduce contact, lower aggression and if differences in resting behavior between unsuccessful and successful pairs occurs this could be another cue to selecting and establishing successful pairs. It should be noted, however, that additional visual barriers aimed at reducing aggression among foxes could limit observations necessary for evaluating pair bonds (see Items 2 through 4 below). Finally, it may be important to increase the size of current and future pens.

2, Design and Construction of Pens to Facilitate Mate Choice – To evaluate mate preference by foxes it is necessary to construct a pen that will facilitate observations and experiments concerning pair preferences and pair bond development. We recommend that new pens be designed at one or more island captive breeding facilities for the express purpose of evaluating pair bond behavior among foxes. By allowing individual foxes to indicate which of several individuals of the opposite sex they prefer, this facility would enable us to set up more compatible pairs less inclined to display aggressive behavior and more likely to reproduce successfully. The design should enable females and males the opportunity to interact with members of either sex, initially without direct contact to avoid injury, but to also allow direct contact between males and females. The pen design could take a variety of forms. One potential design could be similar to an octagon whereby a female or male could be introduced into a run that would allow an individual the opportunity to interact with one or more individuals of the opposite sex housed in adjacent pens (Figure 1). The pen will also have to have a blind for observation and/or video cameras arranged in such a way as to permit complete viewing of the pen area. Please note that the design we have proffered is an example, selection of a final design should consider cost and other ramifications.

3. Behavioral Profile of Successful and Unsuccessful Pairs – To evaluate the reproductive potential of new pairings it is important to identify and understand the behaviors exhibited by successfully mated pairs. Are there significant differences between the behaviors exhibited by successful vs. unsuccessful pairs? Do successful pairs spend more time together? Do they frequently rest together? Do they allogroom? To address such questions, structured behavioral observations should be implemented to develop behavioral profiles (e.g., to assess time allocated toward different behaviors). A comparison of behavioral profiles of successful and unsuccessful pairs can then be used to assist in evaluating the reproductive potential of newly formed pairs.

4. Mate Choice Experiments – Although production in the captive facility on Santa Rosa Island has been relatively high, the captive breeding facility on San Miguel has historically not produced enough pups for sustained releases (Roemer et al. 2001a). Estimates of genetic relatedness and pedigree analysis have been used to form new pairs (Gray et al. 2001), but it is clear that there is a need to devise strategies that may improve mate compatibility and increase productivity.

Once a mate choice pen has been constructed, a series of mate choice experiments should be conducted. For example, (1) "Pair tests" could be carried out where a male and female that have never met before are placed in direct contact with one another and the initial behavioral interactions recorded. These behaviors can then be compared with behavioral profiles of successful and unsuccessful pairs after they have experienced similar separations and reunions and/or (2) "Pair-wise" or "Multiple-pair tests" could be performed to assess female reaction to several males and male reaction to several females. Additional approaches also could be explored (see Mateo 2002, Roberts and Gosling 2004). Data from multiple tests of discrimination may be necessary to evaluate the mechanisms underlying kin recognition and mate choice (Mateo 2003). Data gathered from multiple discrimination tests could be compared to that collected for successful pairs and then be used along with genetic and pedigree information to suggest the most likely pairings for upcoming breeding seasons. Experimental designs for the adopted approaches will have to be rigorously developed and adaptive strategies

also should be incorporated as knowledge is gained from the experiments. These mate choice pens may also be useful for other kinds of studies (e.g., predator recognition and avoidance).

5. MHC Variation and Mate Choice – Recent research in island foxes has shown considerable variation at the Major Histocompatibility Complex (MHC) even in populations of island foxes that were previously shown to be monomorphic at highly-variable nuclear loci (Aguilar et al. 2004). The MHC has been shown to be important in kin recognition and mate choice in fish (Reusch et al. 2001), mice (Penn and Potts 1998, 1999, Potts et al. 1991) and humans (Wedekind et al. 1995) and could play a role in island fox kin recognition and sexual selection as well.

    We recommend that tissue samples for known mated pairs where successful breeding has occurred in the wild (Roemer et al. 2001b) and for those in captivity (Coonan 2003) be assayed for variation at the MHC and be compared to pairs that have not bred in captivity. Such an analysis may yield valuable information that also can be incorporated with existing estimates of relatedness generated with hypervariable loci and pedigree information to suggest future pairings of captive foxes. Drs. Aguilar, Roemer and Wayne have agreed to pursue this research; both field data and tissue samples are already available.

II. Risk Assessment, Population Viability Analysis and the Development of a Mainland Research and Breeding Facility

1. Risk Assessment to Address the Effect of Translocating Foxes to and from the Channel Islands - A mainland research facility would have several advantages in that additional populations of foxes would be established as a safeguard against catastrophic loss on the islands and because research can be more cost-effective given the logistics of building and staffing facilities on the islands. Before such facilities can be developed, protocols for transporting foxes to and from mainland facilities would need to be established as a safeguard against disease transmission. We highly recommend that an immediate effort be undertaken to develop such protocols in concert with 1) existing expertise in fox disease pathology, 2) veterinary expertise from individuals that have developed such protocols for other species and reintroduction programs, and 3) within an inclusive risk-assessment scenario that considers disease risk, and other risks such as the possibility of catastrophic loss and extinction in small populations due to demographic uncertainty. Such an approach is urgently needed.

2. Mainland Research and Breeding Facility – Because of the difficulty of experimentation, continuous observation of captive foxes, and the associated logistical difficulties and expense on the islands, we highly recommend that one or more mainland research and breeding facility be established. These facilities could be used to explore island fox 1) sociobiology (mating, pair bond and kit rearing patterns), 2) reproductive biology (estrus cycle, sperm viability, etc.) and 3) disease relationships. Conditioning experiments (to avoid predation) could also be more easily conducted in a controlled environment. The need for such a facility is paramount but cannot proceed without accomplishing the risk assessment. One or more existing captive breeding facilities willing to commit to island fox breeding and research or organizations willing to develop such a facility need to be identified.

3. Population Viability Analysis to Address the Persistence of the Captive Colonies – Both the San Miguel and Santa Rosa facilities have produced pups that have resulted in a highly skewed

sex ratio that limits the number of pairings (Coonan and Rutz 2003). Prior to the releases of captive animals in 2003, there were 11 unpaired males on San Miguel Island and 19 unpaired females on Santa Rosa Island. Demographic modeling simulated population recovery by releasing 6 to 12 foxes either annually or bi-annually for 10 to 20 years (Roemer et al. 2001a). This simulation suggested that an extirpated population could be recovered but that only the highest release scenarios (i.e., releasing 6 to 12 foxes annually) would allow the population to reach a target population size of 200 animals within 50 years or less (Figure 2). This simulation assumed an equal sex ratio and that all captive individuals released survived, paired and bred on schedules mimicking the wild populations before the recorded population declines. Disease and predation, both factors implicated in the recent population declines, were not included in the analysis. Thus, if the simulations were close to reality, each facility would have to produce 3 to 6 viable pairs of foxes each year to start recovering the extirpated populations.

The aforementioned simulation raises an important question: Can the captive facilities produce enough pairs to maintain the size of the captive facilities (ultimately 20 breeding pairs, which has never been realized) and at the same time produce enough pairs to sustain long-term releases? The recent skew in sex ratio suggests that the production within the captive facilities may not be sufficient to accomplish these tasks. A new simulation using current reproductive data from the captive colonies may help to address this issue. Recent models that optimize approaches and consider cost may be fruitful (Haight et al. 2002, 2004). In sum, additional population viability analyses need to be conducted to address the long-term persistence of the captive facilities and their potential to reestablish extirpated populations.
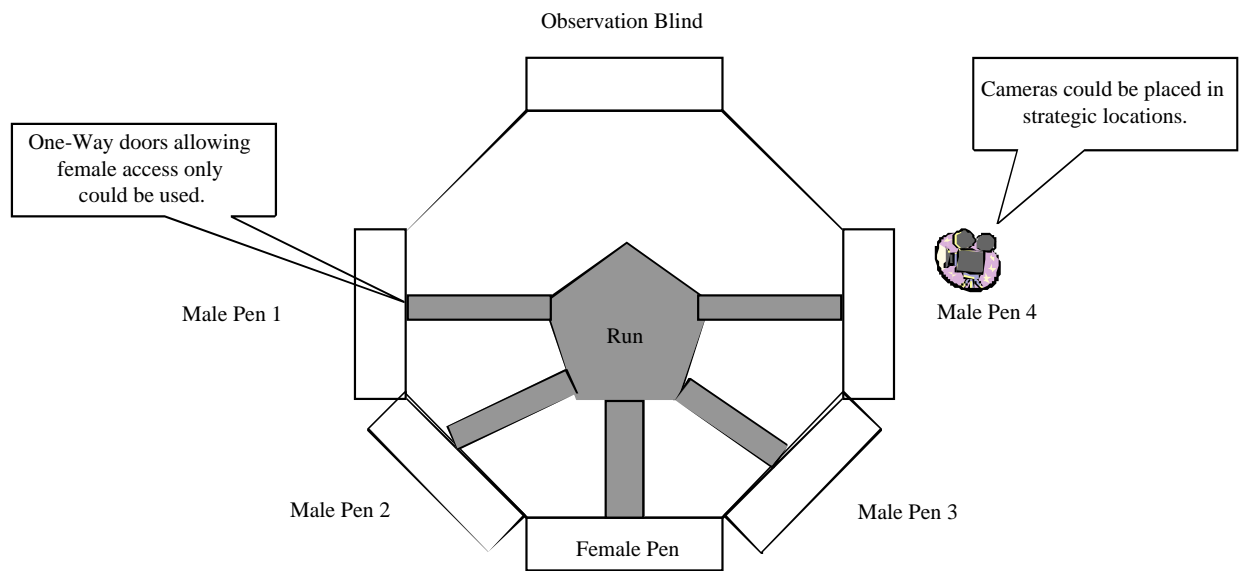
Figure 1. Example of a potential pen design that could be used for assessing mate choice in island foxes. In this design, a female has access to a run that connects her to 4 different pens housing different males. The time a female spends inspecting and interacting with particular males and the behaviors the pair exhibit may be used to indicate female preference.
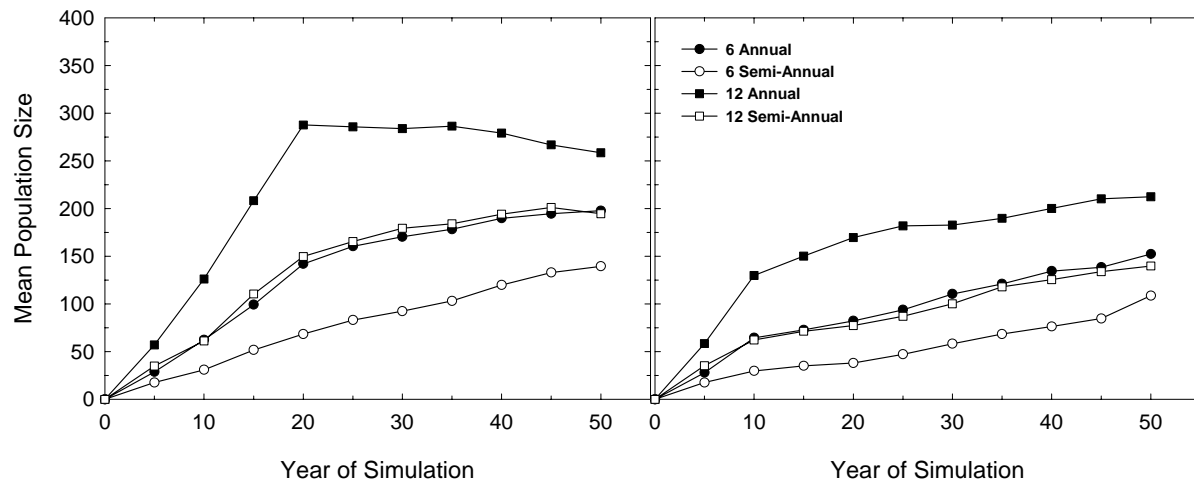
Figure 2. Population trajectories for a simulated San Miguel fox population initiated with captive-born animals and subsequently supplemented with 6 or 12 individuals (equal sex ratio), annually or semi-annually, for a period of twenty years (left panel) or ten years (right panel).

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